

GEOS-CHEM simulations with GEOS-4, and comparisons with previous versions of GEOS-CHEM.

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Acknowledgements

Adaptation of GEOS-CHEM code to GEOS 4 input: B. Yantosca, S. Wu

Work using GEOS-STRAT, GEOS-3 met. data: M. Evans, I. Bey, H. Liu,
R. Martin, R. Park

Data: V. Thouret (MOZAIC)

Plots: I. Megretskaya, B. Yantosca, S. Wu.

Topics

- Some history about differences in prior versions of GEOS-CHEM. Philosophy of continually updating the code led to some confusion about the reasons for changes in results.

Here we focus on changes in OH.

- How do simulations with GEOS-4 (2003) compare to GEOS-3 (2001)? Emissions, chemistry, identical where possible.

Two Different GCMs

GEOS-CHEM Intercomparisons - some history

- V4.26, Sep. 96 - August 97 - “rvm”
GEOS-STRAT. Version used in Martin et al. [2003] paper on aerosol effects, etc
- V5.02, Sep. 96 - August 97 - “bey”
Updated chemistry, GEOS-STRAT (slightly different European emissions, current CH₄, ozone column). Provided by Isabelle Bey
- V5.07.08 2001, GEOS-3 - “mje”
Updated chemistry, interactive aerosols. From Mat Evans.

GEOS-CHEM Intercomparison cont.

- **V5.05.03, 1996 - “hyl”**
Run by Hongyu Liu at Langley using updated chemistry on GEOS-STRAT
- **V5.05.03, 2001, “hyl”**
Run by Hongyu Lui at Langley using updated chemistry on GEOS-3.
- **He did runs with and without clouds**

OH and MCF lifetimes - why were GEOS-STRAT and GEOS-3 runs so different (rvm vs. mje)? Chemistry and dynamics changed, and H. Liu showed the cloud optical depths changed also.

	<u>OH (x 10e6)</u>	<u>CH₃CCl₃ lifetime (yr)</u>	
<u>GEOS-STRAT</u>			
rvm, V. 4.26 Sept. 96-Aug. 97	1.208	5.606	Old Chemistry
bey, V. 5.02 Sept. 96-Aug. 97	1.098	6.244	New chemistry OH is 10% lower
hyl, V. 5.05.03 Jan-Dec., 1996	1.052	6.462	New chemistry OH is ~15% lower
<hr/>			
<u>GEOS-3</u>			
hyl, V. 5.05.03 Jan-Dec., 2001	1.013	6.621	New chemistry GEOS-3
mje, V. 5.07.08 2001	1.076	6.530	same

same input

Clear Sky Simulations

	<u>OH (x 10e6)</u>	<u>CH₃CCl₃ lifetime (y)</u>
▪ hyl, V. 5.05.03 Jan-Dec., 1996	1.068	6.259
▪ hyl, V. 5.05.03 Jan-Dec., 2001	1.000	6.531

Hongyu Liu compared cloud optical depths for GEOS-1, Strat, and -3.

In the tropics, GEOS-1 similar to ISCCP
GEOS-3 similar to MODIS clouds

ISCCP and MODIS very different!

Summary for older versions

- Differences in mean OH are relatively small between GEOS-STRAT and GEOS-3, when the chemistry is the same. Yet the cloud optical depths are rather different.
(We checked that the ozone columns in all runs were very similar).
- There are also differences in tracers caused by different dynamics - not discussed here.

Implementation of GEOS-4 met. fields in GEOS-CHEM.

- This work was done by Bob Yantosca and Shiliang Wu (convection).
This was a major effort.
- Various fields were compared, e.g., clouds, cloud top height, optical depth, precip., water vapor etc.
- Simulations of ^{222}Rn , ^{210}Pb , ^7Be were conducted, and model vs. model plots are available.
 - There appears to be more vigorous convective mixing in GEOS-4
 - There is more downward mixing from the stratosphere at high latitudes in winter in GEOS-4 (noticed after problem identified with ozone data)

GEOS-3 and GEOS-4 Annual Benchmarks

Philosophy:

- **Conduct simulations that are as similar as possible with two sets of met. data - from different GCMs.**

Met. data: GEOS-3 run for 2001, GEOS-4 run for 2003
(same year would have been ideal)

Chemical mechanism and reaction rates: Identical

Emissions:

- **Identical - anthropogenic, biomass burning**
- **Scaled to the same annual total - isoprene, NO_x from lightning**

SYNOZ (stratospheric source of ozone)

- **Spun up for each model (494 Tg/yr in Geos-4)**

Two major differences between simulations with GEOS-3 and GEOS-4

- Chemical budgets, including OH
- Effects of stratospheric input at high latitudes in winter.

Differences in OH, MCF lifetime, ozone prod. and loss

	<u>OH (x 10⁶)</u>	<u>MCF lifetime (yr)</u>	
<u>GEOS-STRAT</u> rvm, V. 4.26 Sept. 96-Aug. 97	1.21	5.61	Old Chem.
<u>GEOS-3</u> V. 5.07.08 2001	1.08	6.53	New chem.
<u>GEOS-4</u> V. 6.01.05 2003	1.17	5.55	New chem

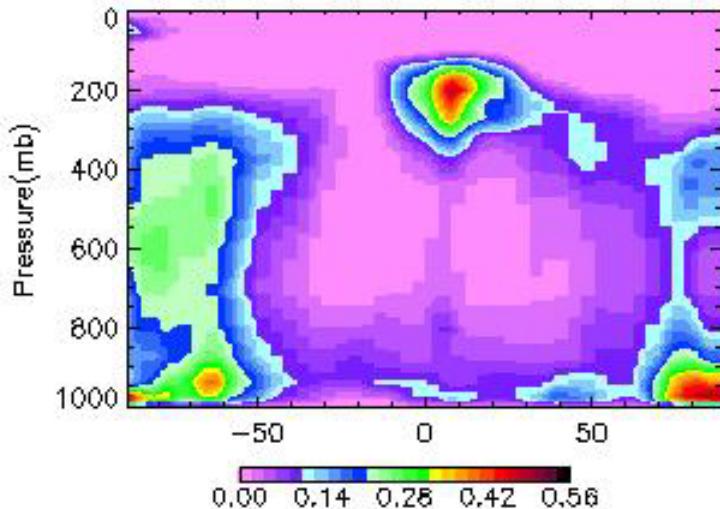
<u>Ozone budget</u>	GEOS-3	GEOS-4	GEOS-STRAT
Prod. ozone (Tg/y)	4383	5087	4924
Loss ozone (Tg/y)	3830	4540	4377

Why did OH change so much?

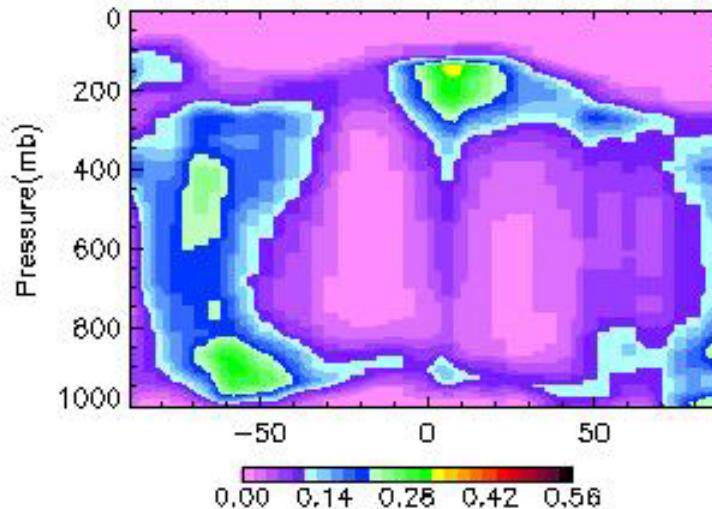
- It is not easy to change mean OH by 10% when the chemistry is the same, water vapor is similar, the ozone column is the same.
- One likely candidate is the cloud optical depth, as these are very different in the tropics.

Total clouds and cloud optical depth

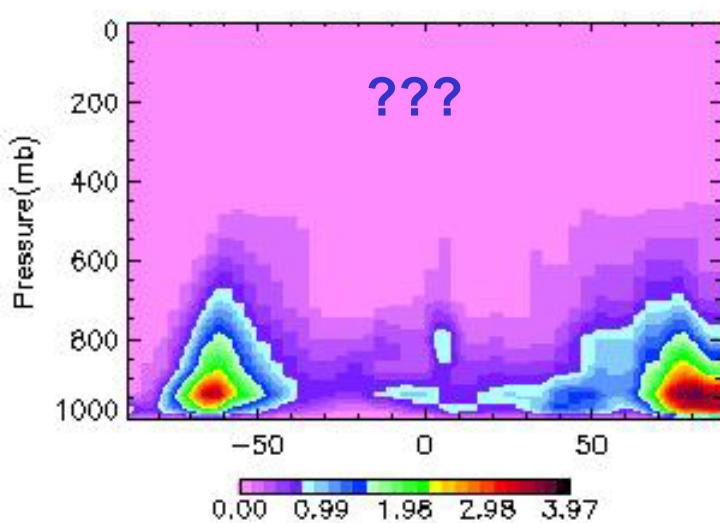
July mean CLDTOT - GEOS_4



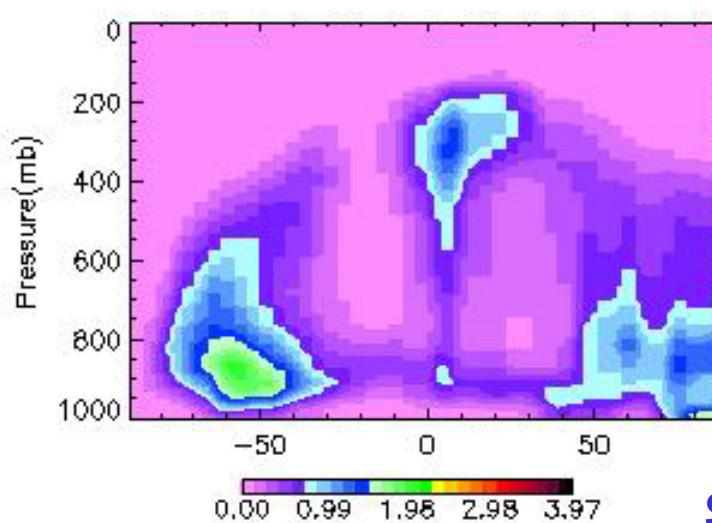
July mean CLDTOT - GEOS_3



July mean OPTDEPTH - GEOS_4



July mean OPTDEPTH - GEOS_3



S. Wu

OH and J(O¹D) in July

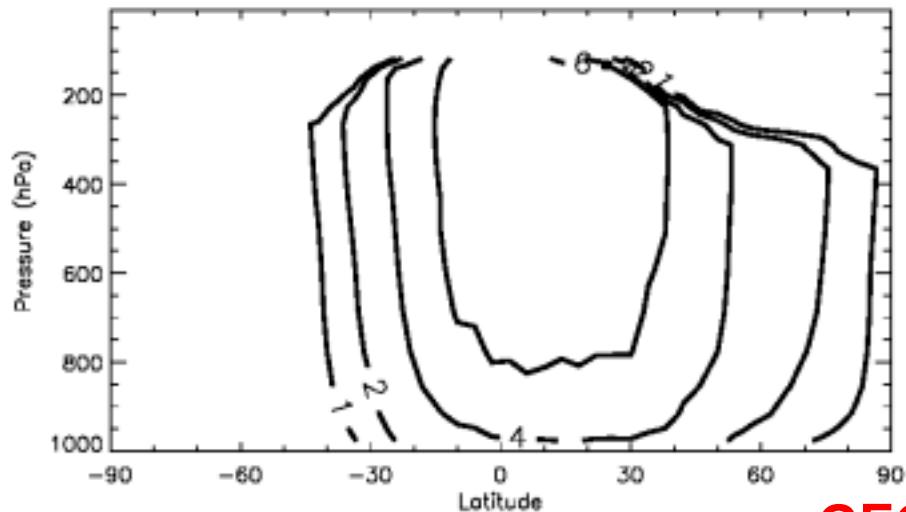
Zonal Mean J(O¹D) (10^{-5} s⁻¹)

Contours : [1, 2, 4, 6, 8, 10, 12, 14]

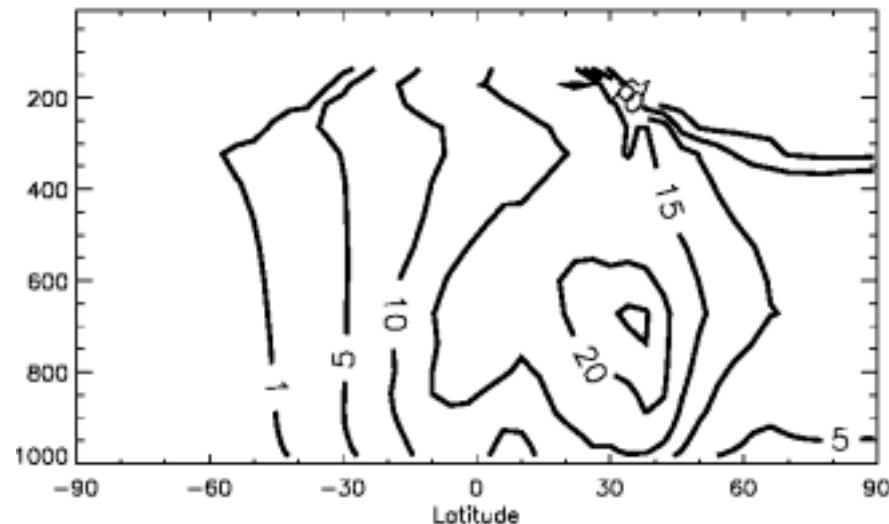
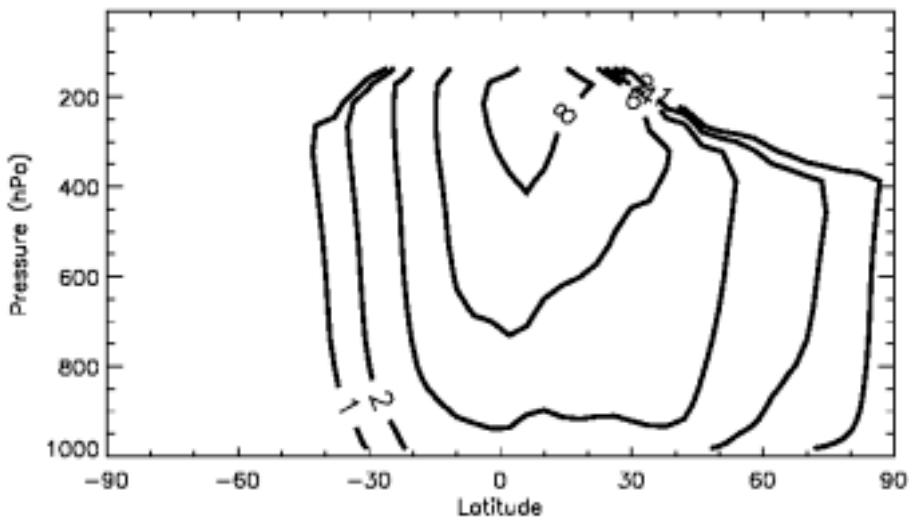
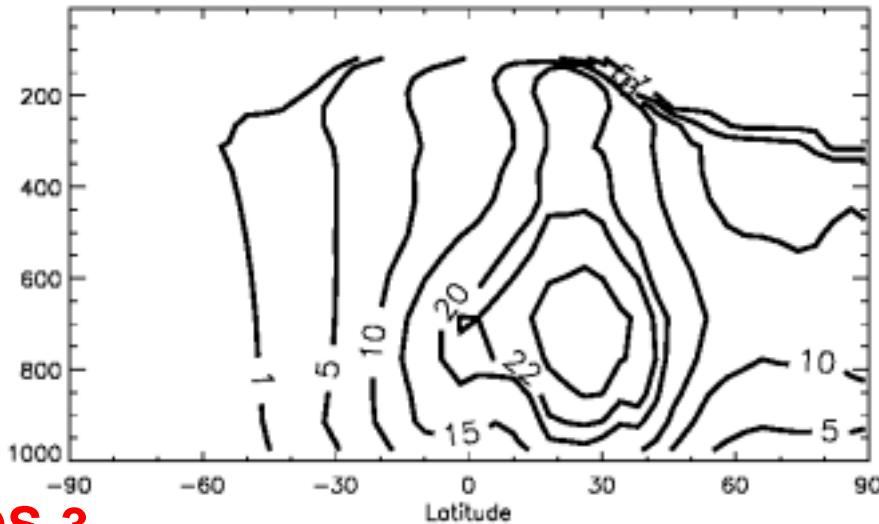
GEOS-4

Zonal Mean OH (10^5 molecules cm⁻³)

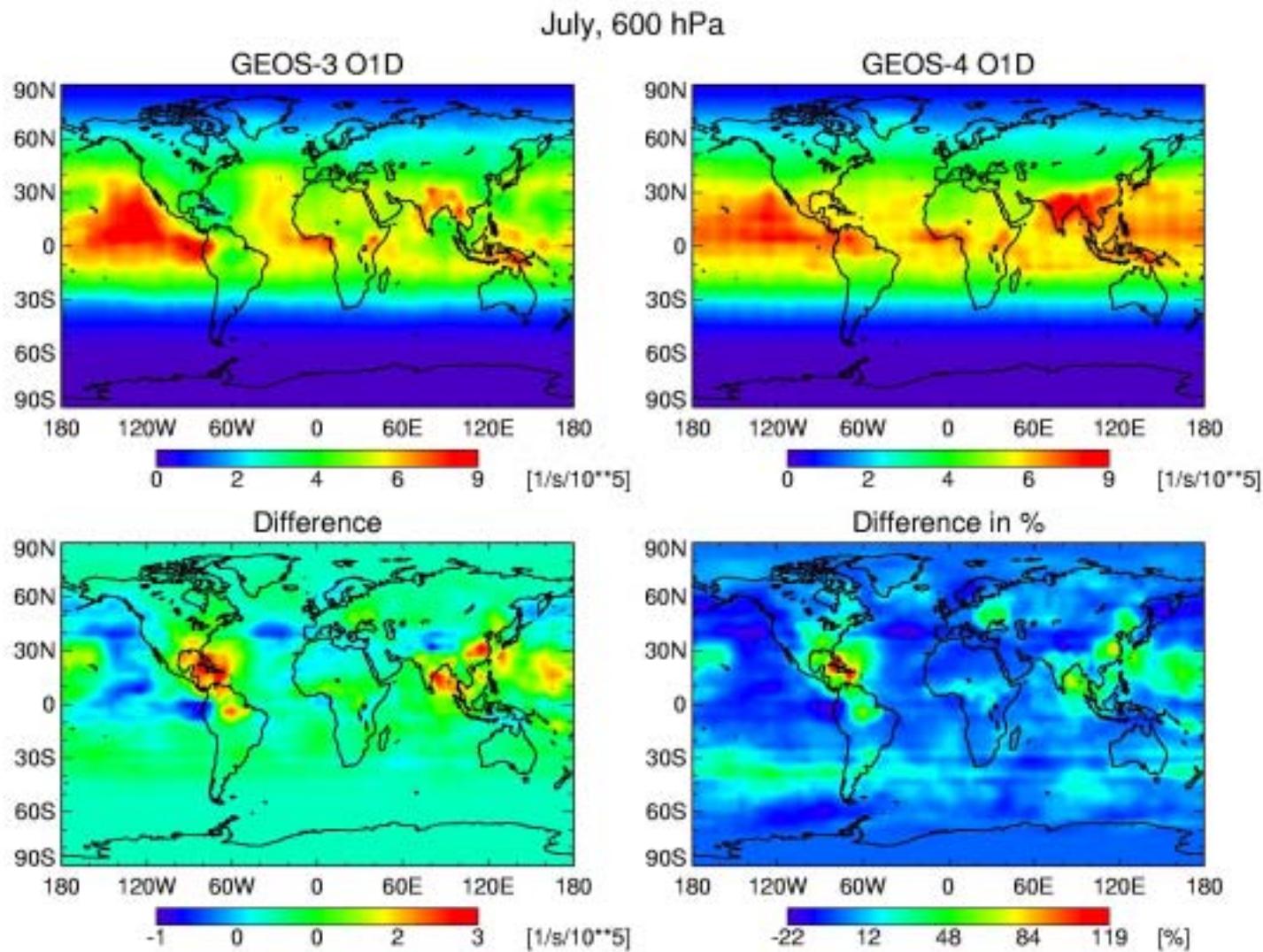
Contours : [1, 5, 10, 15, 20, 22, 25]



GEOS-3

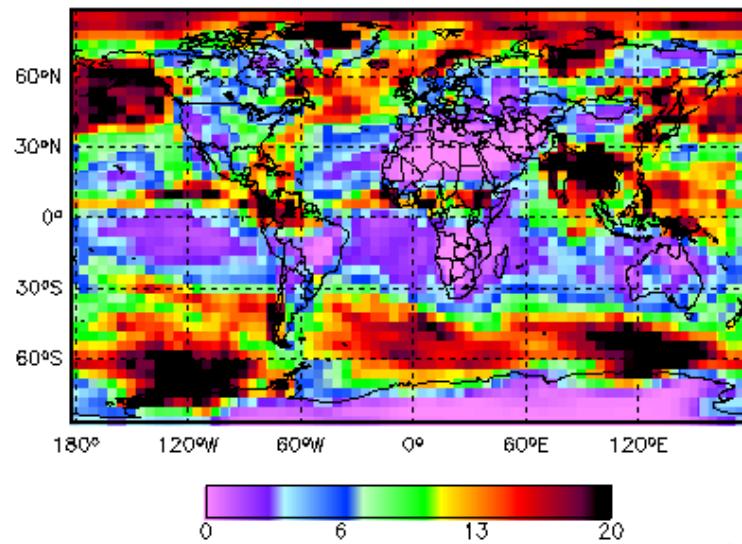


J(O¹D) in July

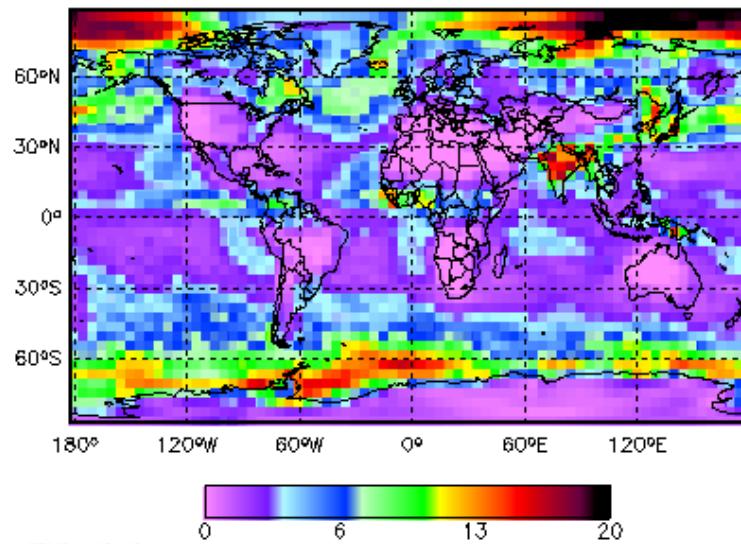


Column optical depth (top) and J(O¹D) at 600 hPa

GEOS-3 Column OD, July 2001

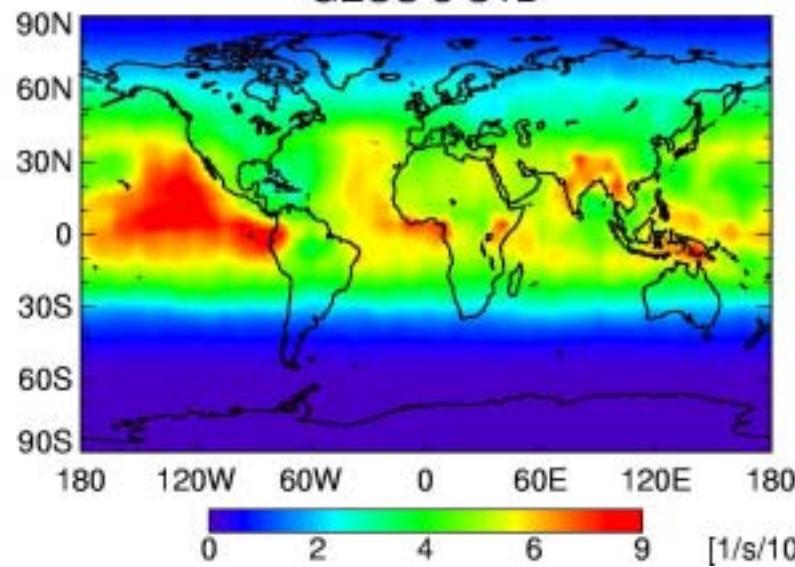


GEOS-4 Column OD, July 2003

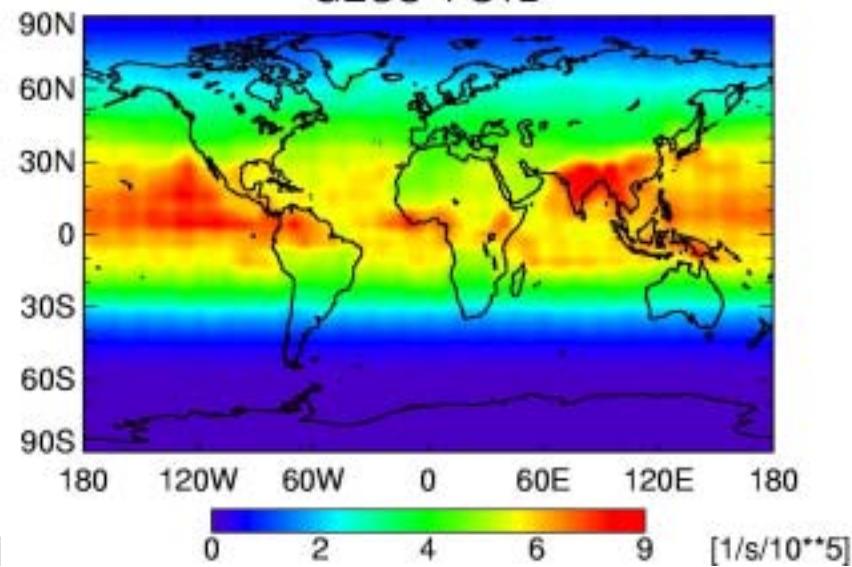


July, 600 hPa

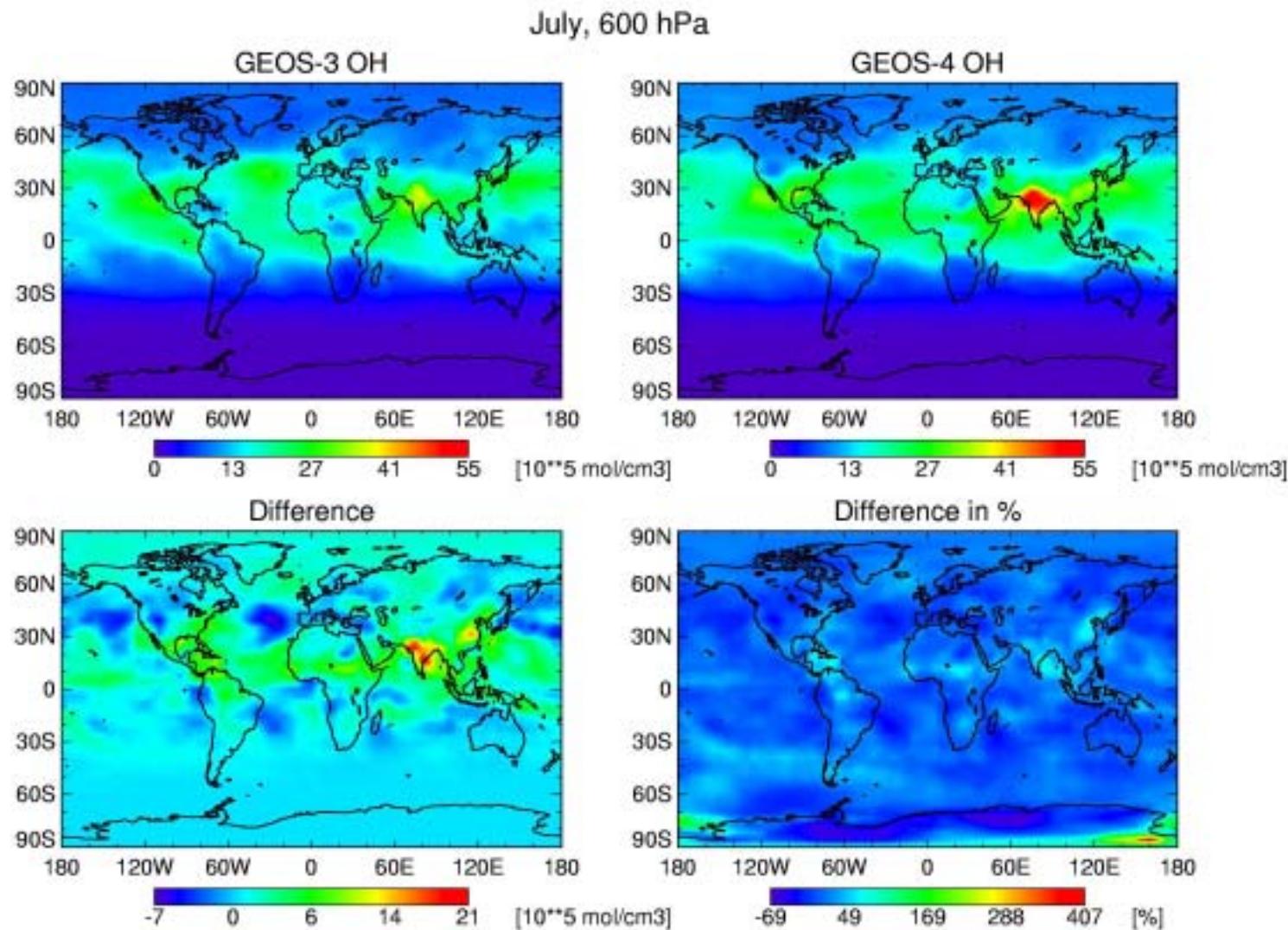
GEOS-3 O1D



GEOS-4 O1D



OH distribution at 600 hPa



Data used for model evaluation

- Ozonesondes – 32 sites
- Surface CO from CMDL, 1992-1997
- Column CO data
- Aircraft data for CO, NO, HNO₃, PAN, H₂O₂, HC_s, from field campaigns (e.g., NASA GTE)

MOZAIC:

- Ozone profiles - 18 locations, several in regions lacking sonde data
- CO profiles, 3 locations (up to 2/03)

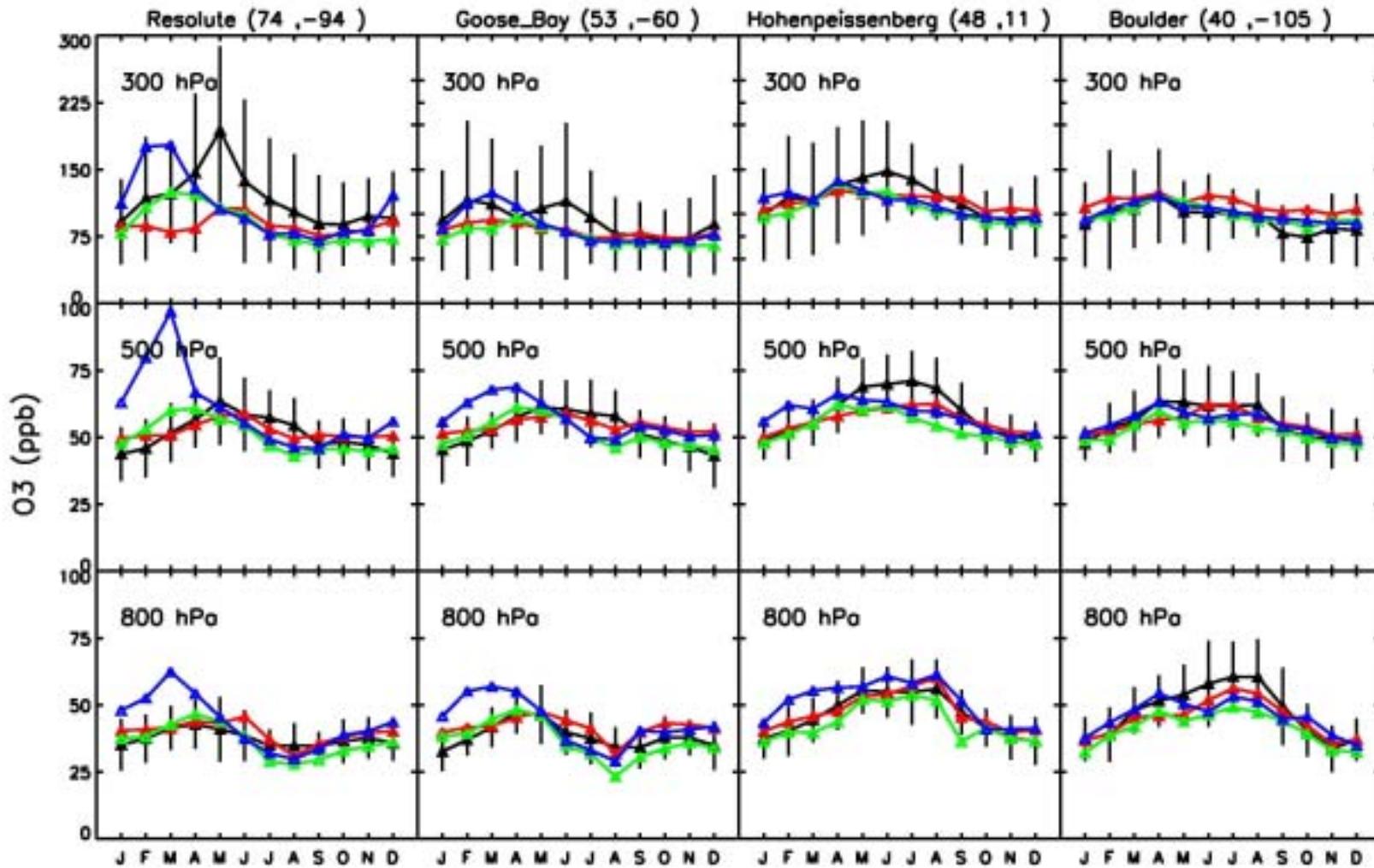
Basic evaluation uses “climatological” data, to examine general characteristics of model, and compare models or versions.

Evaluation of GEOS 4 with 2003 data would require biomass burning and other emissions for 2003.

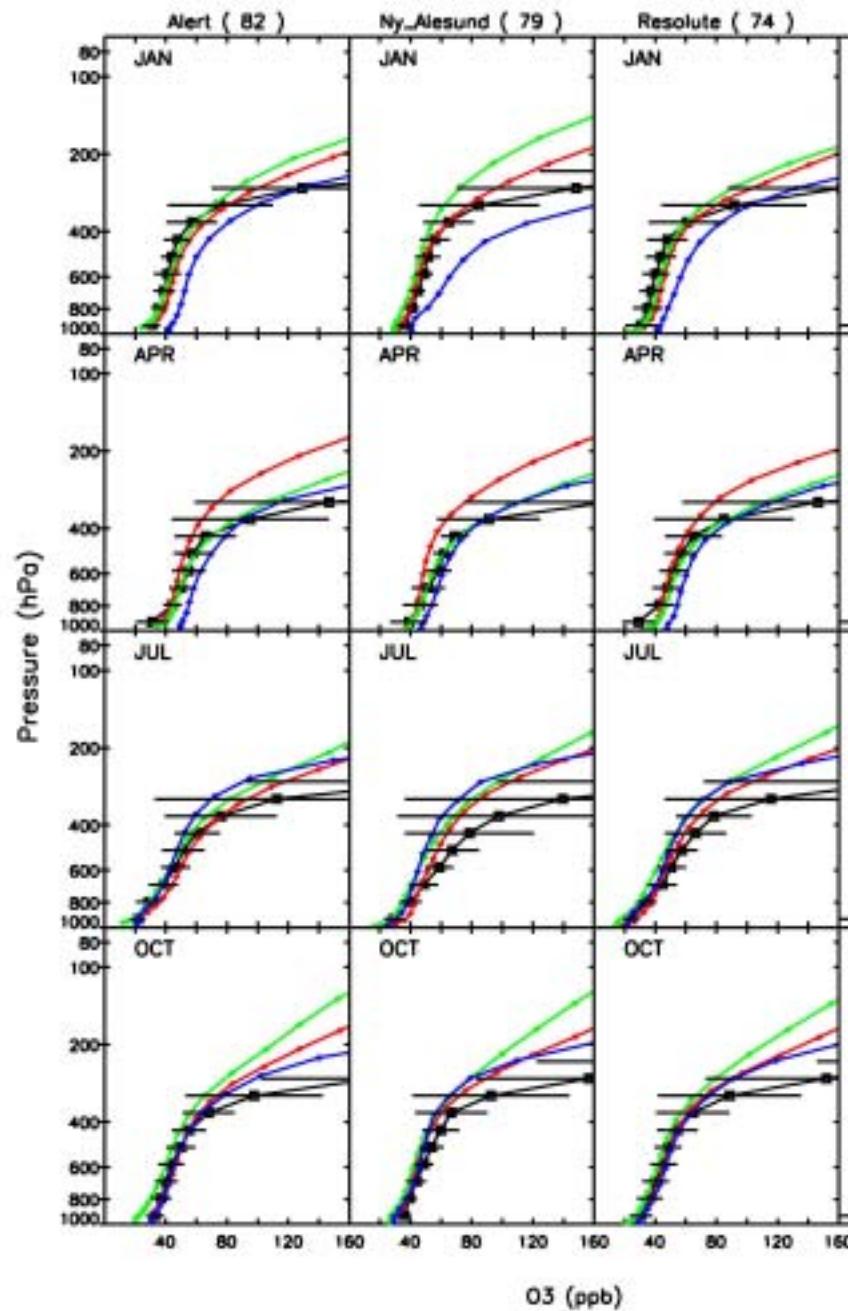
Too much ozone at high latitudes in winter

GEOS-STRAT, GEOS-3, and GEOS-4

1997, V4.26 – red, 2001, V5.07 – green, 2003, V6.01 – blue.



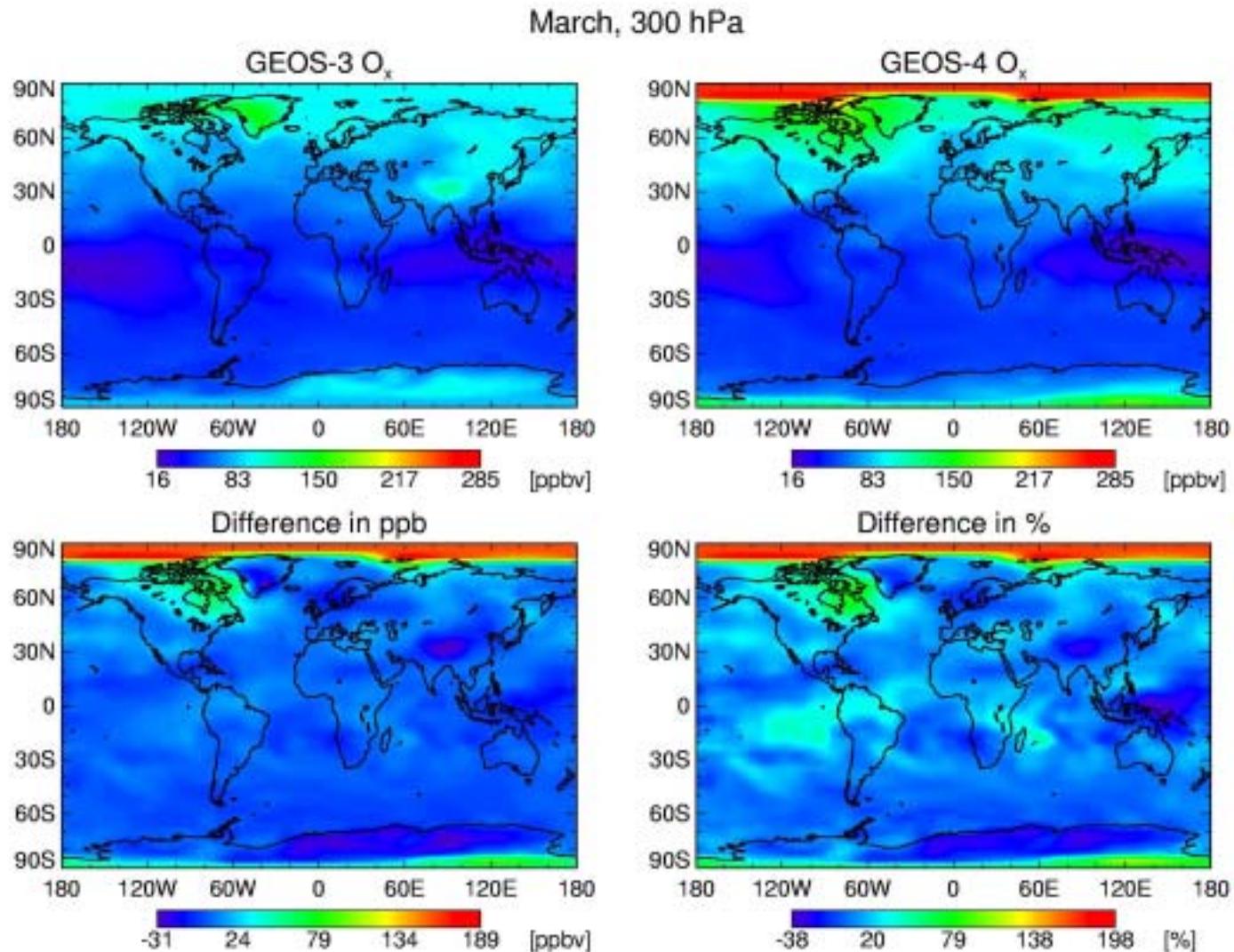
1997, V4.26 – red, 2001, V5.07 – green, 2003, V6.1



Problem varies with longitude.

GEOS-STRAT, GEOS-3,
and GEOS-4

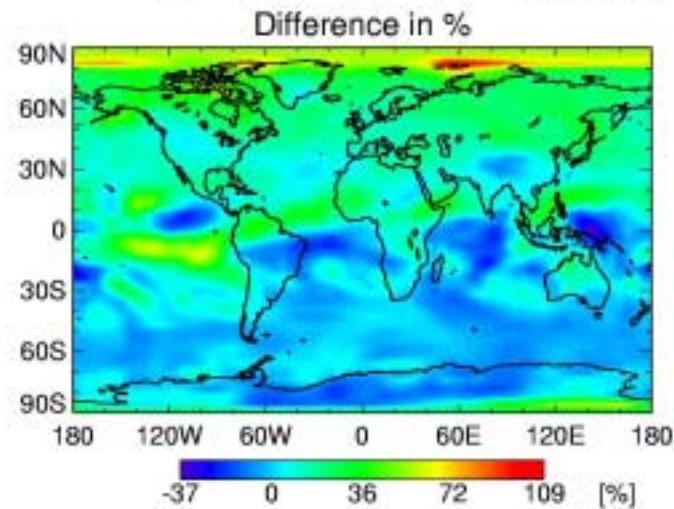
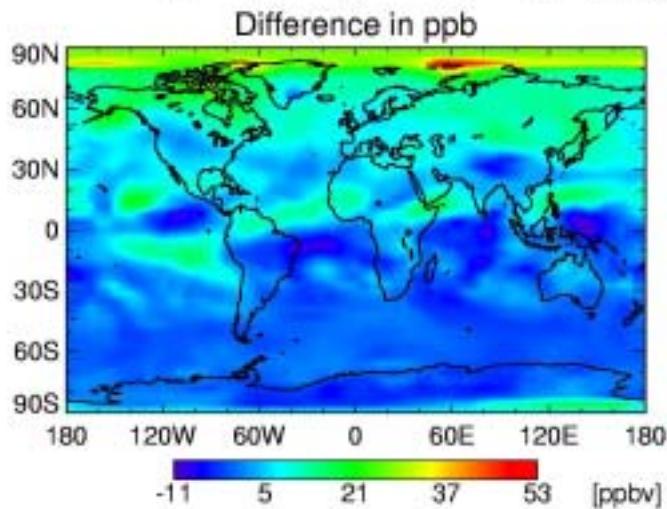
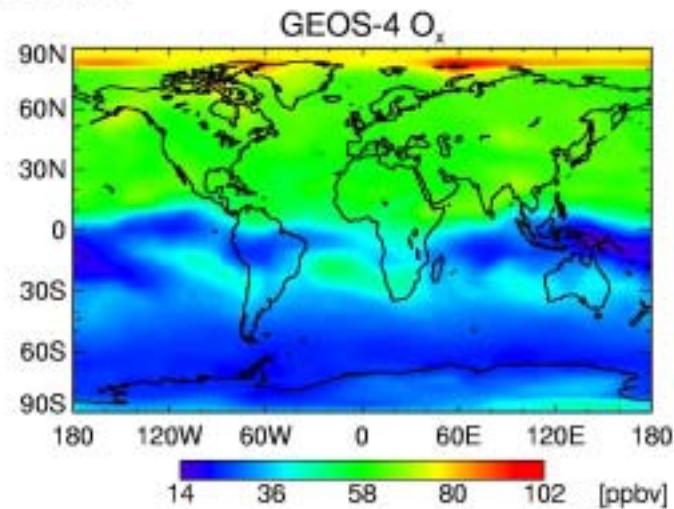
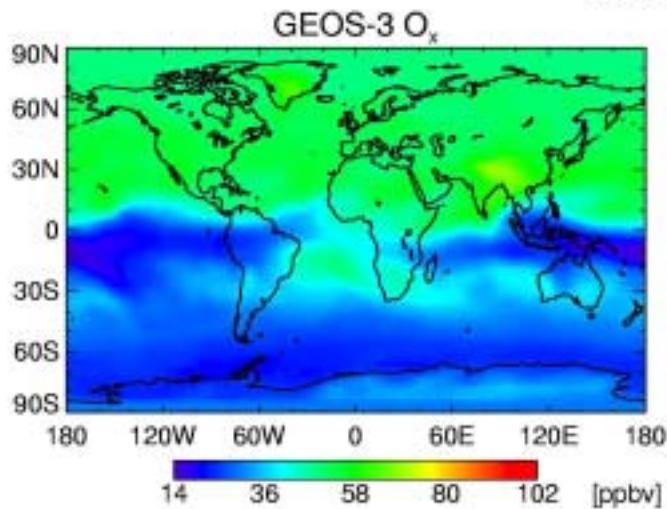
Ozone at 300 hPa in March



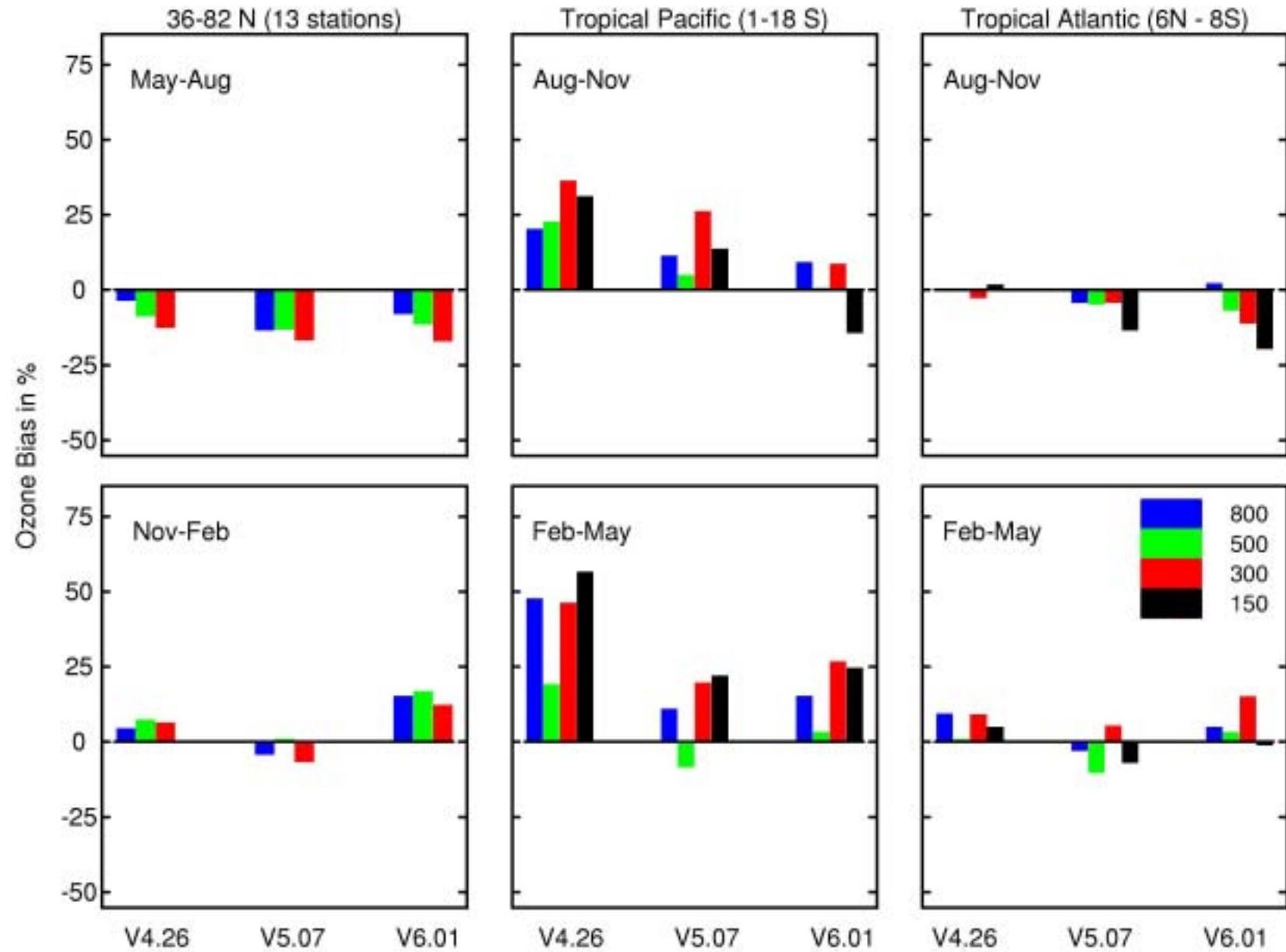
color scales need improved

Ozone at 600 hPa in March

March, 600 hPa



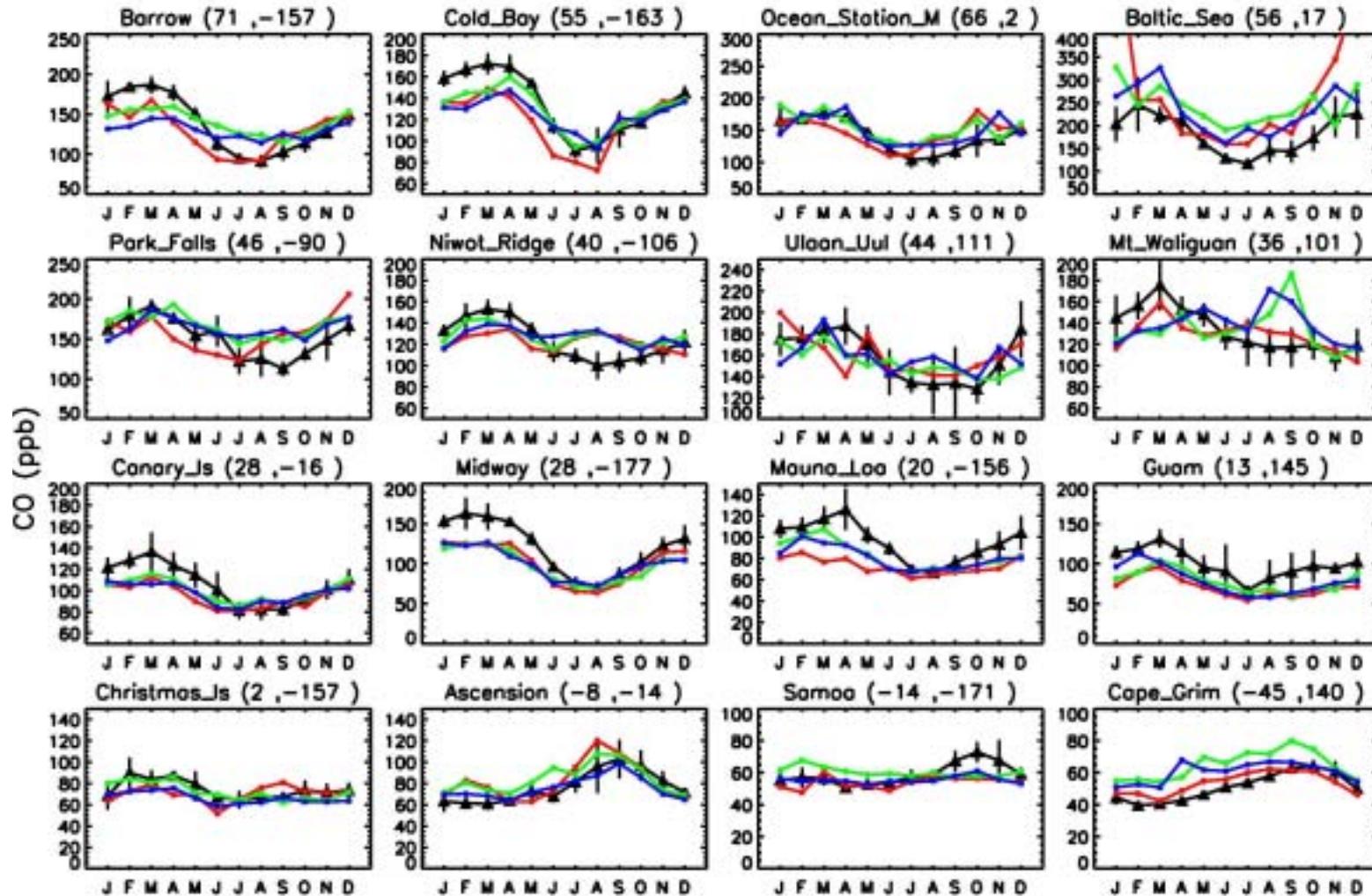
Mean ozone bias, by region



CO, selected sites - differences in detail

GEOS-STRAT, GEOS-3, and GEOS-4

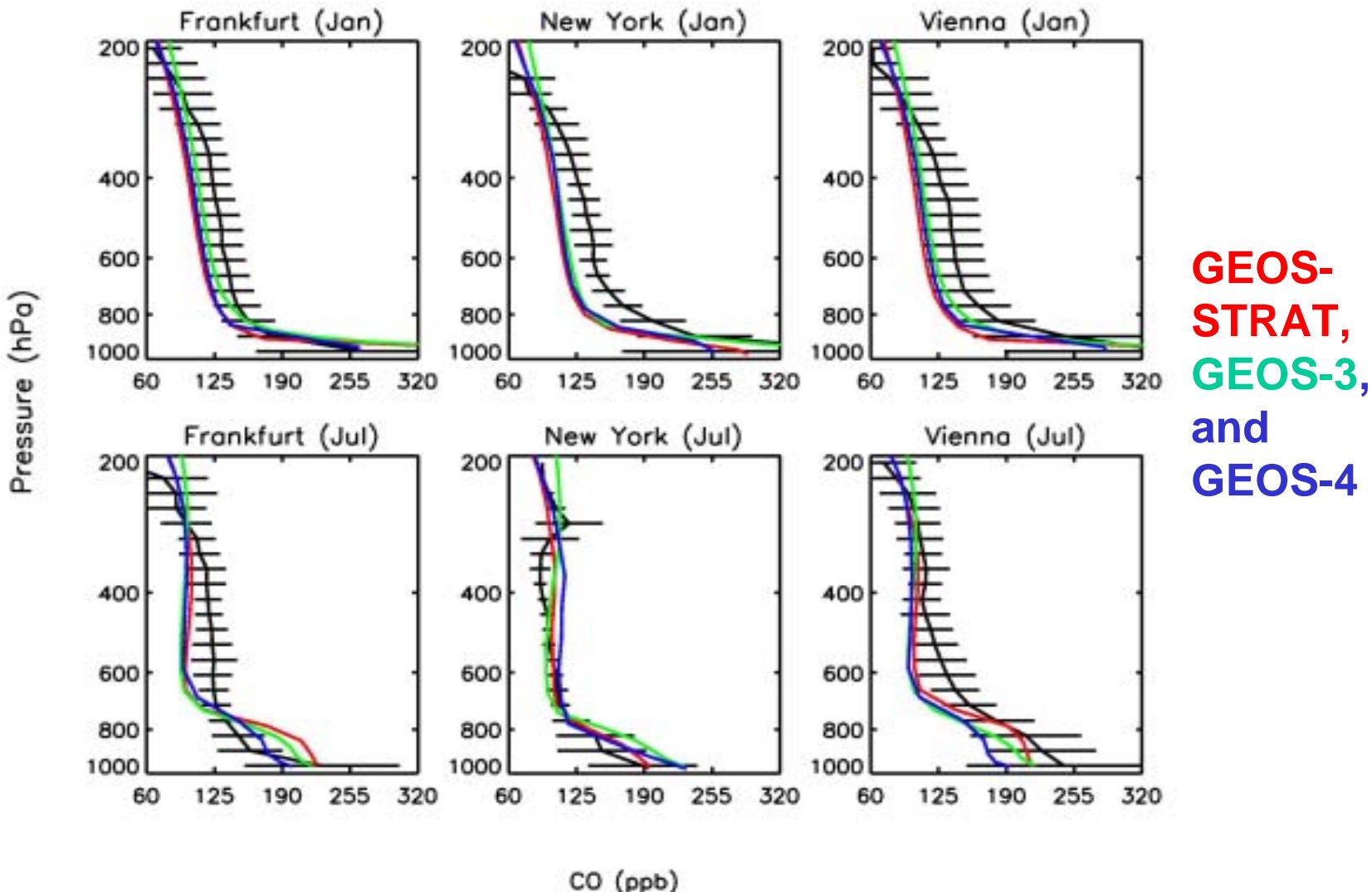
1997, V4.26 – red, 2001, V5.07 – green, 2003, V6.01 – blue.



CO profiles- GEOS-3 and GEOS-4 have different vertical resolution, particularly in the BL.

GEOS 3 and 4 results are similar except near surface

Red: v4–26 (1997); Green: v5–07–08 (2001); Blue: v6–01–05 (2003)

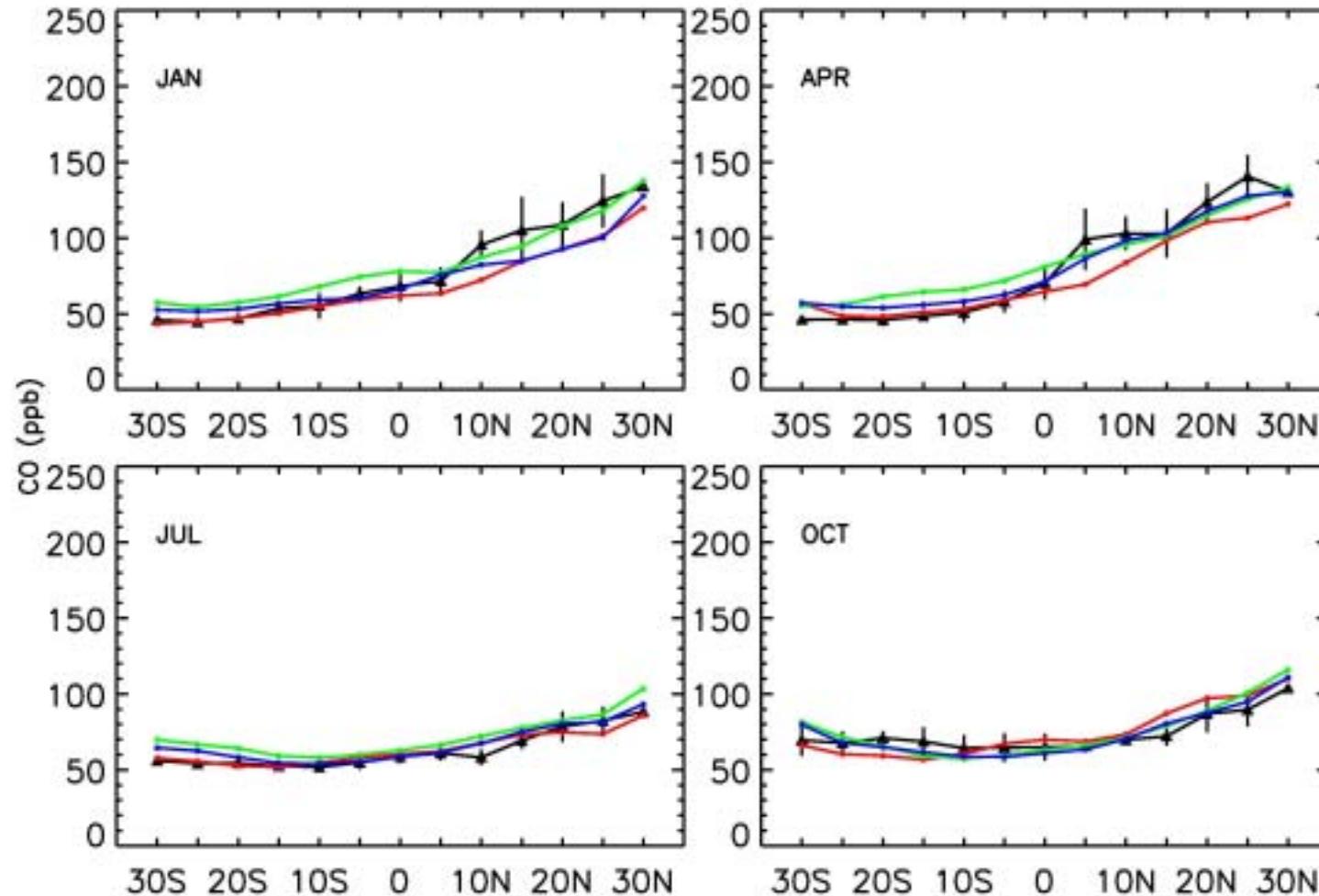


CMDL CO - shipboard data, mid-Pacific

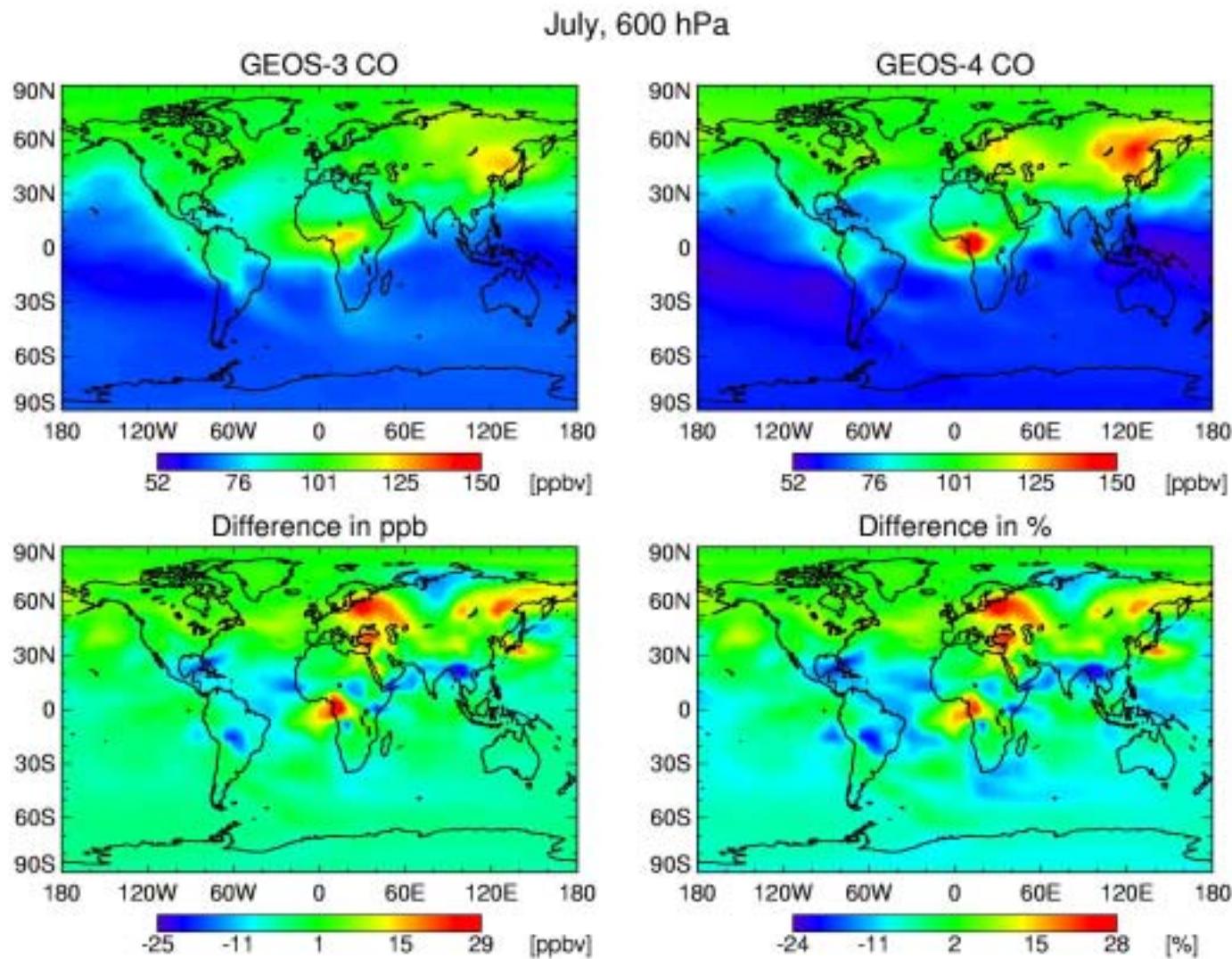
GEOS-4 usually lower than GEOS-3

GEOS-STRAT, GEOS-3, and GEOS-4

1997, V4.26 – red, 2001, V5.07 – green, 2003, V6.01 – blue.



Large differences in spatial patterns



Summary

- **Significant differences in mean OH, that appear to be related to cloud optical depth**
- **Major problem with stratospheric input at high latitudes in winter - treatment of polar boxes, or something else?**
- **Convection more vigorous in GEOS-4 - different GCM**
- **Many differences in detail for various chemical species, but few major biases (obvious biases related to OH differences)**

Locations of ozone profiles used for model evaluation

MOZAIC provides data for 20°-40°N, in the U.S., the Middle East, south and east Asia. Also Africa, S. America.

